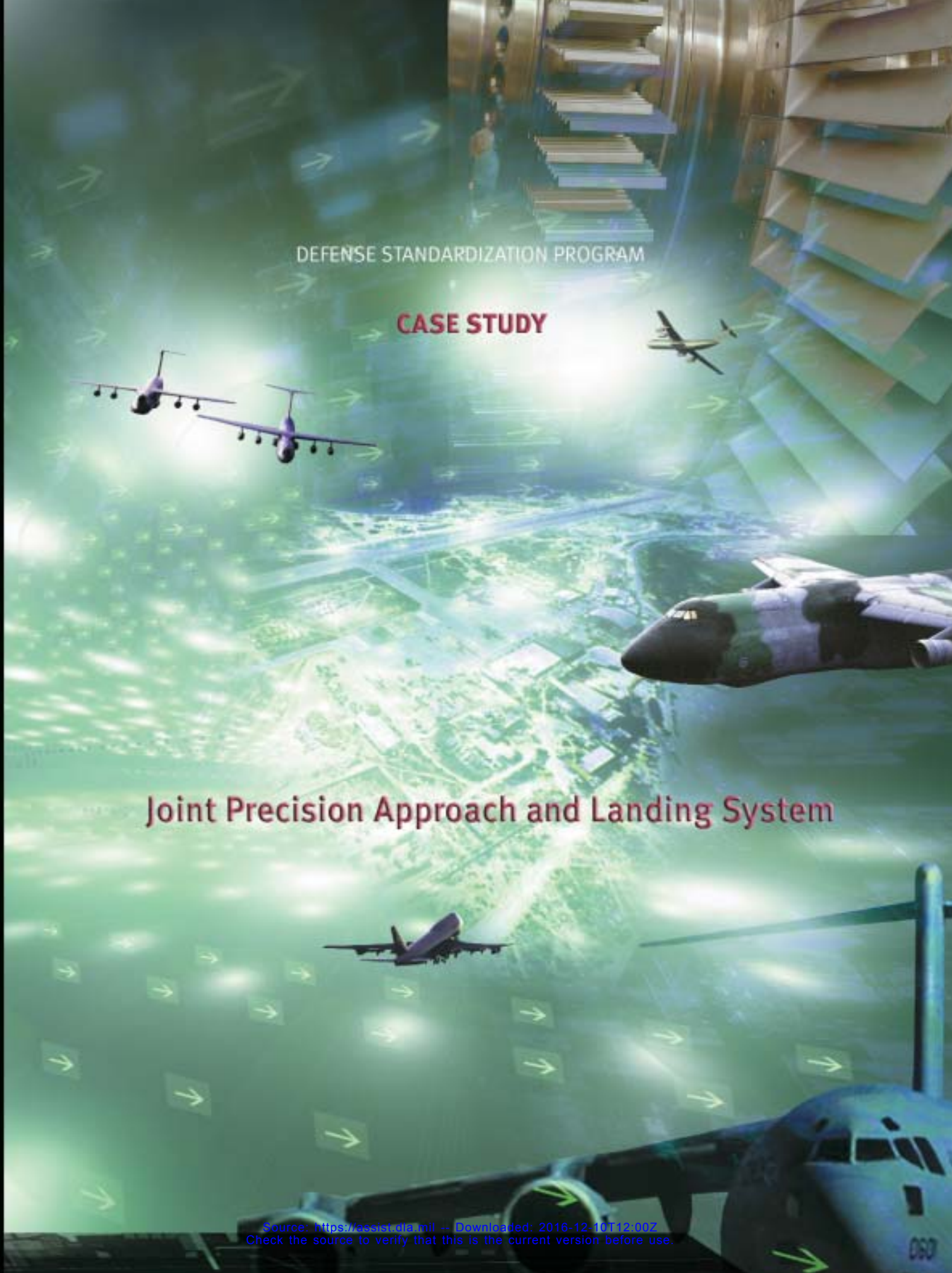

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This case study describes how a DoD team developed the Joint Precision Approach and Landing System (JPALS), making flying much safer, making air traffic management simpler and cheaper, and saving lives and millions of dollars every year.

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Defense Standardization Program Case Study

Joint Precision Approach and Landing System

JPALS Ensures Interoperability, Improves Safety, and Reduces Costs

Background and Problem

The periods of highest risk for aviation accidents occur during takeoff and during approach and landing. In the past, each military service mitigated that risk by developing its own precision landing systems. However, the services' systems were not interoperable, nor were they interoperable with civil systems.

In the early 1990s, DoD recognized the need to develop an improved landing navigation system that would be rapidly deployable, operate in adverse weather and adverse terrain, be survivable and maintainable, and, perhaps most important, be interoperable both with other military systems and with civil-sector systems. DoD also identified two other objectives:

- The system needed to comply with Federal Aviation Administration (FAA), International Civilian Aviation Organization (ICAO), and NATO aviation requirements, policies, and guidelines.
- The system design needed to minimize cost and maximize use of commercial off-the-shelf and nondevelopmental solutions.

None of the numerous military and civil precision landing systems were both suitable and able to meet all of the military's essential objectives. The systems employed different technologies and had limitations that made them undesirable.

To solve the problem, DoD initiated a formal research program. JPALS is a joint military program, with the Air Force as the lead for developing the land-based solution and the Navy as the lead for the shipboard solution. All the military services work together on standardization as well as on operational requirements, acquisition, engineering, system development, and testing plans.

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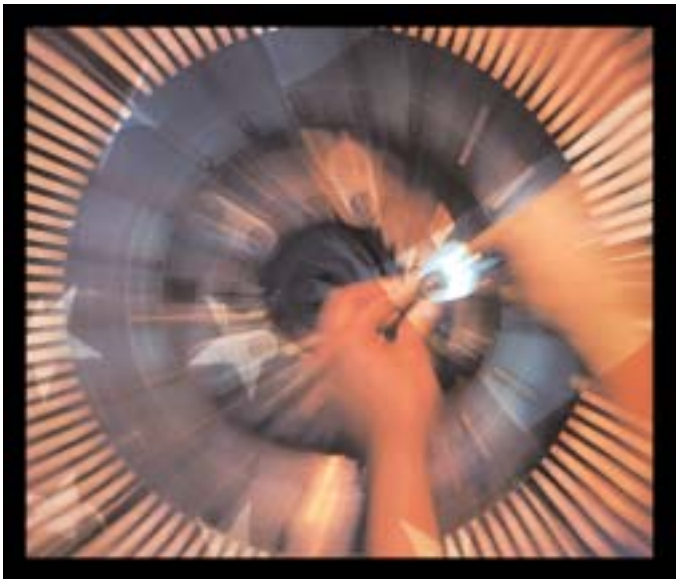
Approach

The JPALS team began its work by conducting market research to identify the best technology for a flexible approach and landing system. The team evaluated 27 different technology alternatives against five key functional objectives and four operational environments. Only one technology—Differential Global Positioning System (DGPS) technology—satisfied all objectives in all operational environments.

Having determined that DGPS was the best solution, JPALS team members immediately recognized that they needed to

- participate in DGPS standards development efforts to ensure that emerging standards would address DoD's needs,
- establish a working partnership with the FAA to ensure that the approach and landing system it developed would meet the diverse needs of military and civil aviation communities,
- involve the aerospace industry to ensure that it would accept the emerging DGPS and JPALS standards,
- collaborate with industry organizations to ensure that the equipment could be used on both military and civil aircraft,
- coordinate with the ICAO to ensure global interoperability, and
- coordinate with NATO's Air Group V to incorporate JPALS-compatible standards into NATO standardization agreements (STANAGs).



DGPS Standards Development

JPALS team members worked with the Radio Technical Commission for Aeronautics (RTCA), a not-for-profit, consensus-based organization that develops standards, to develop fully interoperable dual-use standards for DGPS technology. Several JPALS team members contributed to the first DGPS non-government standard—DO-217, Minimum Aviation System Performance Standards DGNSS Instrument Approach System: Special Category 1—which RTCA published in 1994. DO-217 formed the initial basis for JPALS and the Local Area Augmentation Sys-

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tem (LAAS), the FAA's civilian equivalent to JPALS. Team members' ongoing participation with RTCA also resulted in several other important performance standards related to global positioning and local and wide area augmentation systems, including DO-229, DO-245, DO-246, and DO-253.

Partnership with FAA

To ensure military and civil interoperability, the JPALS team formed a working partnership with the FAA to explore DGPS technology and to foster agreement on standards. The partnership was formalized in 1994 when the Naval Air Warfare Center signed a 5-year interagency agreement through which the FAA funded research and development efforts.

JPALS team members served on the FAA's LAAS Integrity Panel, which developed system architecture and integrity methodology. JPALS team members selected a standard elliptically polarized (EPOL) data link antenna for Navy fighter aircraft—after prototyping and validation by the Navy—and then worked diligently to convince the FAA to adopt the antenna as its LAAS ground station standard. The JPALS team also prototyped DGPS-based avionics equipment and tested the system before the FAA finalized its standards. This cooperation on common standards was critical to ensuring civil/military compatibility at all LAAS-served civil airports.

Involvement with Industry

The JPALS team involved the aerospace industry in the research, prototype development, and testing activities to build broad industry acceptance of the emerging DGPS and JPALS standards. The team awarded study contracts to several different prime contractors. Contractors met quarterly with the JPALS team to discuss progress, promote information sharing, and foster agreement and cooperation on the evolving standard technology. Involving a broad cross-section of the community enabled the development of consensus on the standards and created a ready and experienced cadre of contractors prepared to support the system as it moves toward production.

Collaboration with Industry Organizations

JPALS team members worked with the Airlines Electronic Engineering Committee (AEEC) to ensure development of standards-based dual-use DGPS equipment for commercial and military aircraft. AEEC develops technical standards for avionics architecture and specifications for form, fit, function, and system interfaces. The JPALS/AEEC collaboration focused on civil multimode receivers that incorporate military-unique functionality. This teamwork helped ensure that as JPALS continues to evolve, military and civilian equipment will remain interoperable, enabling

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commercial aircraft to land at military airfields if necessary.

Coordination with ICAO

To ensure international interoperability, the team worked with ICAO's Global Navigation Satellite System Panel to promote compatible international standards. The team promoted ICAO's adoption of compatible technology to ensure that our most important allies will use the same technologies. The ICAO agreed to adopt the JPALS-compatible standards, including the EPOL data link antenna, as its standard.

Coordination with NATO

Members of the JPALS team worked closely with NATO's Air Group V, an organization responsible for coordinating the development of a standard NATO DGPS-based system. Their efforts resulted in the insertion of JPALS-compatible standards into NATO STANAGs 4550 and 4392. These agreements address NATO's use of JPALS technology, ensuring interoperability with our NATO allies.

Outcome

The close coordination among the many communities working on various aspects of precision approach and landing technology resulted in a set of new specifications and standards for DGPS and JPALS that fully satisfy military requirements and DoD objectives, as well as greatly benefit civil aviation.

The Navy and Air Force demonstrated the efficacy of those specifications and standards in tests of JPALS prototypes. The tests proved that DGPS could perform as required, even in high-risk, at-sea auto-landings and operations during hostile jamming:

- The Navy flew an F/A-18 Hornet to successful automatic landings aboard the USS *Theodore Roosevelt*.
- The Air Force landed a C-21 aircraft successfully more then 100 times under severe GPS jamming conditions. It also conducted successful ground station automatic approaches with a Boeing 727.

When fully fielded, the DGPS and JPALS technologies will improve military operations and operations at innumerable civil airfields throughout the world. Moreover, when the technologies are deployed, most of the expensive legacy systems can be eliminated, yielding large savings in infrastructure, operation, and support costs.

DGPS Technology

DGPS technology increases accuracy beyond the basic global positioning system. GPS is a space-based radio-navigation system consisting of a constellation of satellites, a net-

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work of ground stations, and the receivers employed by users. A minimum of 24 GPS satellites orbit the Earth at an altitude of approximately 11,000 miles. A GPS receiver provides users with information on position, velocity, and time anywhere in the world and in all weather conditions by measuring the travel time of signals from four satellites. With such a receiver, users—whether an airplane or ship navigator or a person driving in an unfamiliar city—can calculate their latitude, longitude, and altitude to within about 10 meters.


User Receiving Signals From Four Satellites

The level of accuracy attained with GPS is adequate for many applications. However, it is not accurate enough to guide an aircraft to a precise landing or to guide a ship through dangerous waters. DGPS technology improves accuracy by including a signal from a stationary transmitter as well as from four or more satellites. The stationary site is the key. It ties all the satellite measurements into a fixed local reference p

ith a precisely known position.

JPALS Technology

JPALS uses DGPS technology to dramatically improve precision approach and landing capabilities. The use of that technology, together with standard landing procedures, will permit any properly equipped military or civil aircraft to land at any DGPS-capable air facility—whether at sea or on land or whether military or civil—even during extreme weather conditions.

The effect on military aviation is huge. JPALS-related standards and their implementation in hardware and software will make nearly 14,000 military aircraft, 300 ships, and hundreds of military landing fields safer to operate. Moreover, JPALS will enable the military to have one set of displays and procedures for all landing approaches, whether at O'Hare International Airport or on the USS *Kitty Hawk*. The effect on civil aviation is incalculable.

Ground-Based JPALS

Ground-based JPALS provides very accurate navigation and dependable landing location information to approaching aircraft. The system can calculate an optimal flight path so

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that aircraft can avoid obstructions, restricted airspace zones, and noise abatement areas.

JPALS also will enable the safe use of unmanned aircraft. JPALS will permit unmanned air vehicles to safely take off, fly, land, and closely interoperate with manned aircraft within a common airspace, even under hostile jamming conditions.

Sea-Based JPALS

The Navy's carrier-based version of JPALS is even more accurate than the ground-based JPALS. The carrier-based system uses the ship's inertial navigation system (INS) to compensate for ship motion. The safe landing area aboard a ship is very small. Landing aircraft must stay in the center of the carrier's landing area to avoid other aircraft that may be located a scant 20 feet off either wingtip of the landing aircraft. The Navy requires vertical and horizontal accuracies of less than 6 inches to ensure the effectiveness of the aircraft's arrester hook. By integrating the carrier's INS to correct for deck movement, JPALS achieves the needed accuracy.

The JPALS data link—the technology used to transmit DGPS signals to approaching aircraft—will improve monitoring and control of aircraft operations out to 200 nautical miles. This capability will eliminate the need for the shipboard tactical air navigation system. The data link can provide the ship with each returning aircraft's position, fuel state, weapons status, and maintenance status. This information will improve scheduling and lessen the amount of fuel reserved for flying in a holding pattern. Each aircraft can identify and precisely locate the position of other aircraft within the network. This capability will improve safety and situational awareness in congested conditions. JPALS-equipped aircraft can rendezvous without radio communications, increasing security.

Benefits

The military and civil aviation communities will realize many benefits from the work of the JPALS team. The following are key:

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- Increased safety
  - JPALS will improve traffic management on taxiways and runways, increasing ground safety.
  - JPALS will improve a pilot's situational awareness, increasing safety in the air.
- Reduced cost
  - JPALS will increase aircraft operating efficiencies, reducing operating costs.
  - JPALS will eliminate expensive legacy systems, yielding large infrastructure, operation, and support cost savings.
  - Relatively simple low-cost JPALS equipment will lower system acquisition and support costs.
  - JPALS will reduce the number of required navigation systems onboard aircraft carriers, cutting cost and weight, and freeing valuable avionics space.
  - Because JPALS will enable softer landings, it will lower the wear and tear on aircraft, reducing failure rates and maintenance costs.
  - JPALS simplicity and standardization will reduce pilot training requirements and will lower training costs.
- Improved operations
  - JPALS improved airspace management capability will reduce the required aircraft separation distances and increase the capacity of a given airspace without increased risk.
  - JPALS will enable more efficient and flexible aircraft routing to ease congestion and save time and fuel, especially at high-density airports.
- Enhanced interoperability
  - JPALS standards enable dual-use equipment to support military and civil worldwide aviation and navigation.
  - JPALS standard processes and documentation will enable uniform international operating procedures and training.
  - Military and civil standardization will create one seamless global navigation system for all phases of flight.

In short, JPALS standardization increases safety, saves money, improves operations, and enhances interoperability. From a military viewpoint, that means enhanced global supportability, increased aircraft availability, and improved readiness.

Lessons Learned

The following are the key lessons learned from the JPALS program:

- Participation in the standards development process is essential. The JPALS team worked with several standards development organizations—FAA, ICAO, RTCA,

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AEEC—and with our allies to build consensus on a common set of standards.

- Market research is essential to identify the best technical solutions. The JPALS team evaluated 27 different alternatives to identify DGPS as the best alternative.
- Prototype development and testing can improve standards and build consensus on the right standards. The JPALS team developed and tested the critical elements of the system before finalizing the DGPS standards.
- Teamwork and coordination across organizational lines are essential. The JPALS team worked with the FAA and industry to share resources, minimize duplicative research, and develop dual-use solutions for both military and civil applications.
- Standardizing on off-the-shelf solutions, dual-use technology, and nongovernmental standards saves money, cuts development time, improves interoperability, and expedites system upgrades. The JPALS team selected and then improved GPS technology.

The JPALS team developed a solution with implications far beyond the original problem that they were directed to address. The team achieved a solution so elegant that it will save billions of dollars and many precious lives.

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